INDOOR AIR QUALITY ASSESSMENT

Woodland School
Alphabet Lane
Weston, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
March 2003

Background/Introduction

At the request of Wendy Diotalevi, Director of the Weston Health Department, an indoor air quality assessment was done at the Woodland School, Alphabet Lane, Weston, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA). Concerns about pollutants penetrating into the occupied areas of the building from construction/ renovation activities prompted the assessment.

On January 8, 2003, a visit was made to this school by Mike Feeney, Director of Emergency Response/Indoor Air Quality, BEHA, to conduct an assessment. Mr. Feeney was accompanied at various times by Beth Koch, Health Agent, Weston Board of Health, Robert Ferguson, Director of Elementary School Projects, Town of Weston and Ms. Diotalevi. Findings and recommendations concerning renovations were outlined in a letter sent previously (MDPH, 2003), which is attached as Appendix I. General assessment and air monitoring results are the subject of this report.

The building consists of two wings. The original building was constructed during the 1960s as a single story red brick structure. The original wing was recently renovated and a new wing was under construction at the time of this assessment. Windows are openable.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

This elementary school has a student population of over 180 and a staff of approximately 65. Tests were taken during normal operations at the school and results appear in Tables 1-2.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in four of nineteen areas tested. For the most part, carbon dioxide levels were within the comfort guidelines set by the BEHA indicating adequate air exchange in the majority of areas.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (see Picture 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and a heating/cooling coil, and is then provided to classrooms by motorized fans through fresh air diffusers located at the top of the unit (see Figure 1). Univents were functioning in all classrooms examined. Univents were found blocked with shelves in one room. In order for univents to function as designed, the fresh air diffuser and return vents must be clear of obstacles.

Exhaust ventilation in classrooms is provided by ceiling mounted grilles connected to mechanical fans by ductwork. Exhaust vents were operating in all classrooms surveyed.

In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The ventilation system should be balanced following completion of the renovation/construction project. The last date of balancing of these systems was reportedly in 1996. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult Appendix II.

Temperature measurements ranged from 68^{o} F to 71^{o} F, which were within or close to the lower end of the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity in the building ranged from 23 to 30 percent, which was below the BEHA recommended comfort range in all areas. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several rooms contained a number of plants, some of which were located near univents. Plants should have drip pans to prevent wetting and subsequent mold colonization of window frames. Plant soil and drip pans can also provide a source of mold growth. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from univents and exhaust ventilation to prevent the aerosolization of mold, dirt and pollen. Several areas had planters on carpeting. These planters can be a source of moisture that can chronically moisten carpet and lead to microbial growth. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Once mold growth has occurred, disinfection of some materials may be possible, however since carpeting is a porous surface, disinfection is likely to be ineffective.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. For comments concerning renovations, see Appendix I. Univents are normally equipped with filters that strain particulates from airflow. The air filter in room C133 is of a type that will provide minimal filtration of respirable dusts (see Picture 1). In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by the American Society of Heating Refrigeration and Air-

Conditioning Engineers (ASHRAE) to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by increased resistance (called pressure drop). Prior to any increase of filtration, each univent should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

Several possible sources of irritants existed in classrooms. Many rooms contained dry erase boards. Dry erase board particulates can be easily aerosolized and serve as eye and respiratory irritants. In addition, materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can also be irritating to the eyes, nose and throat.

Conclusions/Recommendations

In view of the findings at the time of the inspection, the following recommendations are made:

1. Implement recommendations listed in previous BEHA correspondence (MDPH, 2003; see Appendix I).
2. Examine each univent for proper function. Survey equipment to ascertain if an adequate air supply exists for each area serviced. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the maintenance and calibration of HVAC equipment and univent fresh air control dampers school-wide.
3. Examine the feasibility of increasing HVAC filter efficiency. For buildings under construction/renovation, more frequent change of air filters is necessary. Filters can

serve as a source of renovation pollutants if saturated with debris. Ensure that installed filters are of a proper size and installed in a manner to eliminate particle bypass of the filter. Note that prior to any increase of filtration, each unit should be evaluated by a ventilation engineer as to whether they can maintain function with more efficient filters.

4. Remove all blockages from univents to ensure adequate airflow.
5. Once both the fresh air supply and the exhaust ventilation are functioning properly, the system should be balanced by an HVAC engineer.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all non-porous surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Relocate plants in close proximity to univent fresh air diffusers. Remove plants in direct contact with carpeting.
8. Acquire current Material Safety Data Sheets for all products that are used in the building that contain hazardous materials (e.g., dry erase markers), including office supplies, in conformance with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).
9. In order to provide self assessment and maintain a good indoor air quality environment on your building, consideration should be give to adopting the US

EPA document, “Tools for Schools”, which can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

10. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH’s website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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Picture 1

Univent Filter in Room C133, Note Accumulation of Debris in Center of Filter

TABLE 1

Indoor Air Test Results – Woodland Elementary School, Weston, Massachusetts– January 8, 2003

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	321	41	41					
Principal Office	665		29	4	Y	Y	Y	
Library	385	71	23	0	N	Y	Y	
C133	583	69	25	11	Y	Y	Y	
Hallway	1262	68	30	1	Y	Y	Y	
Brewer	681	69	26	17	Y	Y	Y	
C154	475	69	24	2	Y	Y	Y	Door open
C156	513	69	25	0	Y	Y	Y	CT 5
C151	668	70	26	21	Y	Y	Y	Door open
C159	697	70	25	20	Y	Y	Y	Supply sealed

*** ppm = parts per million parts of air**
CT = water-damaged ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Woodland Elementary School, Weston, Massachusetts– January 8, 2003

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Art Room	1660	70	28	45	Y	Y	Y	
D100	729	70	26	19	Y	Y	Y	
C149	974	71	28	2	N	Y	Y	Door open
ESL	1063	70	29	0	N	Y	Y	
Gym	418	70	20	0	N	Y	Y	
D114	611	70	25	18	Y	Y	Y	
Band	778	69	25	0	Y	Y	Y	
Cafeteria D126	473	71	26	2	Y	Y	Y	Exhaust open to ceiling system
Main Office	437	71	23	1	Y	Y	Y	Door open
Teachers Lounge	499	69	23	8	N	Y	Y	

*** ppm = parts per million parts of air**
CT = water-damaged ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
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	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Carbon Monoxide and Particulate Testing
Woodland School, Weston, MA –January 9, 2003

Area	Carbon Monoxide *ppm
Outside (Background)	0
Principal's Office	0
Library	0
C133	0
Hallway at sealed door	0
Brewer classroom	0
C154	0
C156	0
C151	0
C159	0
Art	2
Hallway Intersection near food prep	2
D100	0
C149	2

* ppm = parts per million

[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

TABLE 3

Carbon Monoxide and Particulate Testing
Woodland School, Weston, MA –January 9, 2003

Area	Carbon Monoxide *ppm
ESL	2
Gymnasium	0
D114	0
Band room	0
Cafeteria	0
Main office	0
Teacher's Lounge	0

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

TABLE 1
Particulate Testing
Woodland School, Weston, MA –January 9, 2003

Area	Location in Area	Number of Ultrafine Particulates Particles per cc of air (in thousands)[a]
Outside (Background)	Side of building	11
Principal's Office	Center of room	5
Library	Center of room	6
C133	Center of room At electrical socket At seam in light fixture	18 21 46
Hallway at sealed door	In hallway 3 feet from sealed door At seam at top of during, occupied side	71
Brewer classroom	Center of room	12
C154	Center of room	12
C156	Center of room	10
C151	Center of room	11
C159	Center of room	10

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

Appendix I

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
Bureau of Environmental Health Assessment
250 Washington Street, Boston, MA 02108-4619

February 4, 2003

Wendy Diotalevi
Town Hall
P.O. Box 378
Weston, MA 02181

Dear Ms. Diotalevi:

As you know, after consultation with your office, the Bureau of Environmental Health Assessment (BEHA), Emergency Response/Indoor Air Quality (ER/IAQ), was invited to conduct an evaluation of the indoor air quality at the Woodland School. Concerns of excessive dust within occupied areas of the building attributed to construction/renovation activities and reports of a temporary evacuation of room 133 prompted the assessment. Michael Feeney, Director of the ER/IAQ program, conducted the assessment on January 9, 2003. Mr. Feeney was accompanied by Beth Koch, Weston Board of Health and in part by Robert Ferguson, Director of Elementary School Projects, Town of Weston and you. Preliminary information concerning renovations is the subject of this letter. It is important to note that the State Department of Education amended their regulations in 1999 to address such concerns for school renovation projects in Massachusetts (MDOE, 1999). General assessment and air monitoring results will be subject of a separate report.

The school is currently under renovation while occupied by students, teachers and administrative staff. At the time of the inspection, the western portion of the school was under renovation. The hallway door leading to the renovation site was sealed with duct tape and plastic sheeting (see Picture 1). In addition, fiberglass insulation was inserted between the roof decking and the interior wall of the room that is adjacent to the area under renovation to provide a barrier (see Picture 2). An examination of the shared interior wall of room 133 was conducted. Cold air was noted penetrating into the classroom from the renovation area through (three) electrical sockets in the wall as well as light fixtures in the ceiling plenum (see Pictures 3 and 4). Unsealed spaces were also seen around pipes penetrating into the ceiling plenum.

The interior of the univent in classroom 133 was also examined. The fresh air intake louver was set to allow minimum air infiltration. The operation of the univent to draw minimal fresh air from outdoors will limit the dilution of pollutants in this room. Univent filters were of a type that would provide minimal filtration of renovation pollutants (see Picture 5). In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed in these units. Changes of filter medium in buildings under renovation should be increased to avoid saturation of the filter, which in turn can cause the filter to release pollutants.

In order to assess whether containment measures were effective to prevent pollutant migration from construction areas into occupied areas of the school, air monitoring for ultrafine particles (UFPs) was conducted. Carbon monoxide air levels were also measured. Air tests for carbon monoxide were taken with the TSI, Q-Trak ™, IAQ Monitor Model 8551. Air tests for ultrafine particulates were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525. The tests were taken under normal operating conditions. Test results appear in Tables 1-3.

During the assessment, detectable levels [1 to 2 parts per million (ppm)] of carbon monoxide were recorded in several rooms and the hallway intersection near the door adjacent to renovations (see Tables). The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). No carbon monoxide measurements exceeded the NAAQS for carbon monoxide during the assessment.

The combustion of fossil fuels, welding, steel cutting, concrete/brick boring and other renovation activities can produce particulate matter that is of a small diameter (<10 μm) (UFPs), which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles of a diameter of 10 μm or less was used to identify pollutant pathways from the renovation site into occupied areas.

The instrument used by BEHA staff to conduct air monitoring for UFPs counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitoring is useful in that it can track and identify the source of airborne pollutants by counting the actual number of airborne particles. The source of particle production can be identified by moving the UFP counter through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increase as the UFP counter is moved closer to the source of particle production. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or that particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether the NAAQS PM_{10} standard was exceeded. The primary purpose of these tests at the school was *to identify and reduce/prevent pollutant pathways*. Air monitoring for UFPs was conducted in classrooms, hallways and other areas, which may be directly impacted from renovation activities. For comparison, measurements in areas away from renovation sites indoors as well as outdoors were taken. Increased levels of UFPs over background levels taken in the interior of the school were noted in some areas, with the highest concentrations at the electrical outlets and light fixtures in room C133 and the sealed door in the main hallway. The level of UFPs measured in these areas when compared to the library (the farthest point from the renovations) indicates that particulates from construction activities ***are*** penetrating into occupied space into the hallway and room C133.

A number of conditions that influence the movement of air from renovation areas into occupied areas were observed. These include:

1. *Temperature Differentiation between Areas under Renovation and Occupied Spaces*: The renovation areas are open to the outdoors. Temperature in the renovation areas would be expected to have a lower temperature than occupied areas during the heating season. This temperature differentiation can result in movement of cold air from the renovation site to warmer air, creating drafts that can penetrate through cracks, crevices, holes and seams in interior and containment walls, resulting in the introduction of renovation generated pollutants (e.g. vehicle exhaust, particulates) into occupied areas.

2. *Occupied Areas Are under Negative Pressure:* The operation of room exhaust vents combined with deactivated or poorly operating unit ventilators creates negative pressure. If classrooms are under negative pressure (similar to a vacuum effect), air and pollutants from the renovation areas can be drawn into classrooms through cracks, crevices, holes and seams in interior and containment walls.

3. *The Renovation Areas Are under Positive Pressure*-The renovation areas can become pressurized during westerly winds. A number of open-air penetrations exist in the exterior wall. A steady westerly or easterly wind can force air into the renovation area, which creates positive air pressure. If pressurized, air and pollutants from the renovation areas can be forced into classrooms through cracks, crevices, holes and seams in interior and containment walls.

The carbon monoxide and ultrafine particulate air testing indicate that seams (some sealed with duct tape) and spaces in temporary containment walls are not sufficient to prevent pollutant migration into occupied areas. Measures should be taken to reverse the air pressure relationship between the renovation areas and occupied spaces. Univents in all occupied classrooms should be operating to create positive pressure in classrooms. Once all univents are operating, general exhaust ventilation in classrooms should be reduced to maintain a slightly positive air pressure in classrooms.

Despite measures taken thus far to limit pollutant migration into occupied areas, pathways still exist for pollutants to move from areas under renovation into occupied spaces. In addition to changing the pressure relationships of the occupied space to the areas under renovation, the following recommendations should be implemented as soon as possible in order to reduce the migration of renovation generated pollutants into occupied areas and to better address indoor air quality concerns:

1. Establish communications between all parties involved with building renovations to prevent potential IAQ problems. Develop a forum for occupants to express concerns about renovations as well as a program to resolve IAQ issues.

2. Develop a notification system for building occupants immediately adjacent to construction activities to report construction/renovation related odors and/or dusts problems to the building administrator. Have these concerns relayed to the contractor in a manner to allow for a timely remediation of the problem.

3. When possible, schedule projects which produce large amounts of dusts, odors and emissions during unoccupied periods or periods of low occupancy.

4. Disseminate scheduling itinerary to all affected parties, this can be done in the form of meetings, newsletters or weekly bulletins.

5. Obtain Material Safety Data Sheets (MSDS) for all construction materials used during renovations and keep them in an area that is accessible to all individuals during periods of building operations as required by the Massachusetts Right-To-Know Act (MGL, 1983).

6. Consult MSDS' for any material applied to the affected area during renovation(s) including any sealant, carpet adhesive, tile mastic, flooring and/or roofing materials. Provide proper ventilation and allow sufficient curing time as per the manufacturer's instructions concerning these materials.

7. Use local exhaust ventilation and isolation techniques to control for renovation pollutants. Precautions should be taken to avoid the re-entrainment of these materials into the building's HVAC system. The design of each system must be assessed to determine how it may be impacted by renovation activities. Specific HVAC protection requirements pertain to the return, central filtration and supply components of the ventilation system. This may entail shutting down systems (when possible) during periods of heavy construction and demolition, ensuring systems are isolated from contaminated environments, sealing ventilation openings with plastic and utilizing filters with a higher dust spot efficiency where needed (SMACNA, 1995).

8. Seal utility holes, electrical sockets, light fixtures, spaces in and around temporary walls and holes in interior walls of occupied areas adjacent to renovation areas to eliminate pollutant paths of migration.

9. Seal all doors that access renovations with polyethylene plastic and duct tape on both sides of door.

10. Consider installing an air lock in areas that lead from the construction activities to the occupied section of the building. An airlock can be established by erecting a temporary wall with a door in close proximity to either an existing wall with door or another temporary wall with door. Each wall should be covered with continuous sheets of polyethylene plastic adhered with duct tape to seals seams in each airlock wall. Each door should be equipped with weather-stripping and a door sweep to prevent air movement through seams once the door is closed. Each door of the airlock should be equipped with a spring to automatically close the door. This configuration serves to prevent renovation generated pollutants from penetrating into occupied space. In order to prevent dust spread,

a floor covering to aid in removal of particle debris from workers shoes (walk-off mat) should be installed on the floor of the air lock. Another walk-off mat (approximately five feet in length should be installed in the occupied side of the airlock. The purpose of walk-off mats is to limit the spread of dust from workers walking from the renovation side in occupied areas. Each walk-off mat should be cleaned with a HEPA filter equipped vacuum daily, or more frequently if needed.

11. If possible, relocate susceptible persons and those with pre-existing medical conditions (e.g. hypersensitivity, asthma) away from areas of renovations.

12. Implement prudent housekeeping and work site practices to minimize exposure to renovation pollutants. This may include constructing barriers, sealing off areas, and temporarily relocating furniture and supplies. To control for dusts, a high efficiency particulate arrestance filter (HEPA) equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended.

We suggest that most of these steps be taken on any renovation project within a public building. Please feel free to contact us at (617) 624-5757 if you are in need of further information or technical assistance.

Sincerely,

Suzanne K. Condon, Assistant Commissioner
Bureau of Environmental Health Assessment

cc/ Mike Feeney, Director, Emergency Response/Indoor Air Quality, BEHA
Alan Oliff, District Superintendent, Weston School District
Debra L Dunn, School Principal, Woodland School
Beth Koch, Weston Board of Health
Christine Lynch, Administrator, MDOE, School Building Assistance Unit
Eugene Benoit, US EPA Region I
Senator Susan C. Fargo
Representative Alice Hanlon Pelsch

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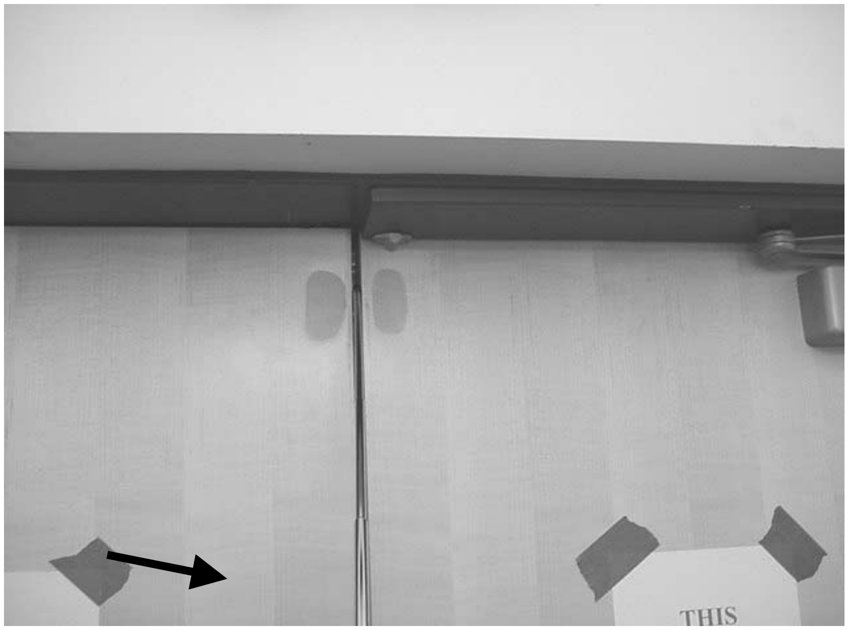
Picture 1



Hallway Door near Food Prep Area, Note Seam in Tape

Picture 2

Fiberglass Insulation Inserted into Interior Wall/Roof Deck Joint in Room 133

Picture 3

Electrical Sockets in Room 133

Picture 4

Light Fixture in Room 133. Note Space in Ceiling at Edge of Fixture

Picture 5

Filter of Room 133 Univent, Note Light Passing through Filter